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Equivalent Queueing Petri Net Expression for New Routing Method under RWP Mobility in Dtns

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Abstract: In our previously published study, we have proposed a new routing method, named OOPFE in (Yang *et al*., 2012) and proposed the basic approach for using QPN to model the routing method under RWP-mobility in DTNs. In this study, not only we model the important features of OOPFE but also propose two different methods to model the same problem. Thus, in addition to note the interesting features in the random distribution. We can select easily method from equivalent methods to simulate. In fully understand QPN analytical tool, we can simulate the future problems which needs performance analysis or solve some problems which is difficult analysis by mathematical method.

Key words: Mobile Ad Hoc networks, queueing petri net, delay tolerant networks, protocol routing, OOPFE, IMT

INTRODUCTION

We have proposed a basic method in the study (Jiang *et al*., 2013), for using QPN tools to model the routing method under RWP-mobility in DTNs. And the values of simulation results compare the values of theory analysis are more than 95% confidence interval. Therefore, we prove the QPN is not only a very powerful tools for design a new routing in advance to estimate effect, but also for verify the effectiveness for check the performance of new routing method. This study will present the advanced features and try to use different ways but equivalent result for a same problem to get a same result.

RELATED WORKS

Related research to use PN Model in Ad-Hoc networks: There are many related analysis or application have been proposed for using Pns in Ad hoc. For instance, (Zeng *et al*., 2010) uses PNs to model and analyze different data management schemes in sensor data storage. In Zhang and Zhou (2003) uses PNs to discuss the approach of simulation and analysis in Ad Hoc network. In (Jamali and Khosravi, 2011), the study uses CPNs to establish the AOMDV (Ad Hoc On demand Multipath Distance Vector routing) and the DSR (Dynamic Source Routing) for performance comparison in MANET.

In study (Jiang *et al*., 2013) is our study to propose the basic ways for using QPN to model the routing method under RWP-mobility in DTNs.

RWP-mobility: In the study (Groenevelt, 2005) has analyzed the Inter Meeting Time (IMT). And propose the IMT will be exponentially distributed, so, the intensity of exponential distribution is λ, which means that an average of $1/\lambda$ of the time, expect to encounter again. Therefore, we can estimate the latency of 2Hop-Routing under the RWP-mobility.

2Hop-Routing and OOPFE-Routing in DTNs: The routing method in (Groenevelt *et al*., 2005), referred to as "two-hop" (abbreviated with "2hop" to represent). According to two-hop protocol, the source node along its route and copy the message to all nodes including the destination node. Those nodes which receive the message, only can forward the message to the destination node.

In our previous routing studies (Jiang and Chen, 2011), we have designed a new routing scheme to combine the advantages of multi-copy and single copy, called OOP-routing in delay tolerant mobile ad hoc networks. There are 3 main steps to process the message. The full name of OOP is OB (One Broadcast), OC (One Copy) and PS (Persistent Storage). We further improve to become the OOPFE routing, the new routing method suitable for the size of network scenarios is bigger or the speed of source node is slower.

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FIRST METHOD: USING QPN TO MODEL 2-HOP ROUTING UNDER RWP MOBILITY IN DTNS

Markov chain for 2hop-routing: In order to easily use QPN to express the multi-hop routing. We make some simplifications for the routing problem. Refer literature (Groenevelt, 2005) in 2005, that study has described how to create a Markov chain model and derived the mathematical formula.

As shown in Fig. 1, it is a Markov chain transition diagram for 2Hop-Routing in exponential distribution of intensity λ. From this figure, we can calculate the delay time from the source node to the destination node.

Using QPN to model 2Hop-routing: In 2Hop routing, the numbers of nodes are (N+1). So, when N = 3, the numbers of nodes are (3+1) = 4. We care about the three important Queueing place, named Imt1, Imt2, Imt3. Their parameters of intensity all are λ. After finishing a QPN analysis, we can get the value of Latency which is very similar as the theoretical values. The results show in Figure 2, the Latency is the time difference from "BR place" to "DBuf place". The Latency is 409 sec.

In another example, when N=6+1, the numbers of nodes are (6+1) =7. We care about the three important Queueing place, named Imt1 ~ Imt6. Their parameters of intensity all are λ. After finishing a QPN analysis, we can get the value of Latency which is very similar as the theoretical values. The results show in Fig. 3, the Latency is the time difference from "BR place" to "DBuf place". The Latency is 300 sec.

SECOND METHOD: USING QPN TO MODEL NO "OB-PROCESS" OF OOPFE-ROUTING IN RWP MOBILITY

We have proposed a new routing method, named "OOPFE". For simplify the problem, we will focus on the feature of no "OB-process".

In "One Broadcast" process of OOPFE routing, due to the distribution of nodes are too sparse, only very little or no neighbor node directly adjacent to the node. So, the simulation can be simplified and can be easier to understand and the feature of OOPFE will be same as the famous routing method, named 2hop-Routing.

Therefore, this study we consider no any neighbor node in "One Broadcast" process. We will discuss these issues in other study.

Basic Markov chain for no "OB-process" in OOPFE routing: If there is not any neighbor node in the "One broadcast" process of OOPFE routing, the simplify

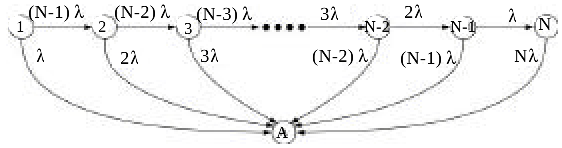

Fig. 1: Two-hop multi-copy protocol transition diagram of the Markov chain for the number of copies

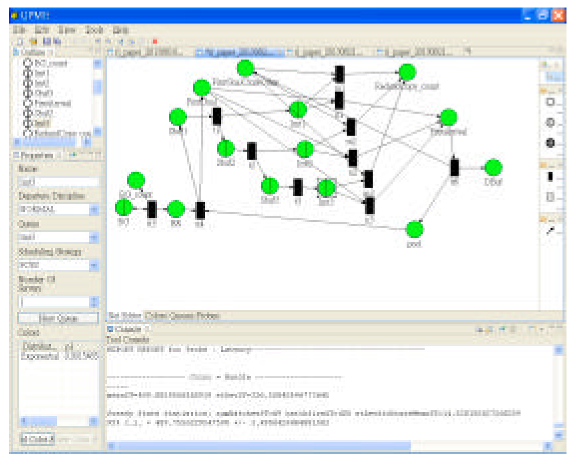

Fig. 2: Experiment of 2Hop (N=3+1) in QPN. The Latency is 409

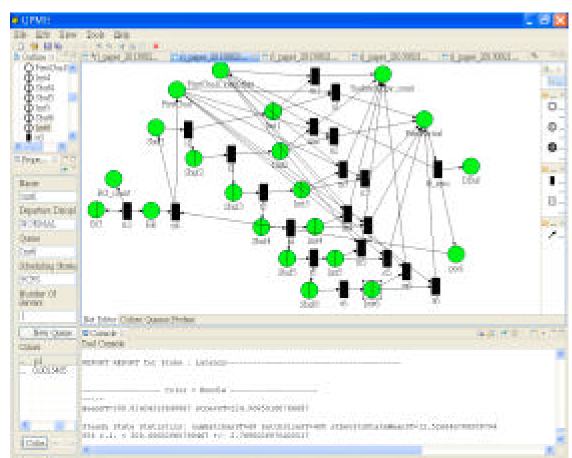

Fig. 3: Experiment of 2Hop (N=6+1) in QPN. The Latency is 300

version of OOPFE is same as 2Hop routing. Therefore, the following discussion will be directly research the 2Hop-routing.

Because the main difference between the two routings is the role replacement, we can say that: 2Hop is like a man finish 400 meters race. But, the OOPFE is like four people in the run 400 meters relay, everyone ran only 100 meters.

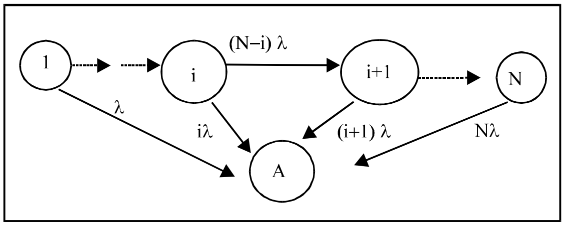

Fig. 4: Markov chain transition diagram and omit "One broadcast" process in OOPFE routing

Refer to previously discussed in Fig. 1, it is the 2Hop multi-copy Markov state transition diagram.

In that figure, when the number of the circle is 1, which means that the source node meets other node, excluding destination node and the probability is (n-1) λ.

In this condition, the 2Hop and the OOPFE are same. The number of the circle is 2, which means that the difference between the OOPFE and the 2Hop are only one. That is change role. The source node will transform the right of copy to the first encounter node. So, the next node will obey the probability is (n-2) λ to encounter the third node, but the 2Hop will still the source node obey the same probability to encounter the third node.

Refer Fig. 4, the number in circle indicates the amount of replication message has been completed. We start with a source node to know this information, so the QPN is start with a number one inside the circle. And after the average inter-meeting time, that is 1/ (λ). We can expect the source node will encounter the destination node "A". After i times copy, we use a circle contains the number i to represent. So, these i nodes can meet the node A after the time is 1/(iλ).

And the node, finally get the baton, it is also possible in 1/(N-i) λ, the average time encounter other (N-i) one does not know the message node. Once (i+1) nodes know the message, the average time to meet the destination node will be reduced to 1/((i +1) λ). Finally in addition to the destination node N nodes outside all know this message, we can expect in the time (1/Nλ) to encounter the destination node.

Although the OOPFE and the 2Hop applicable to different scenarios. However, according to Markov chain transition diagram view, the OOPFE and the 2Hop will get the same QPN.

Thus, repeated explanation is omitted. We can directly used the QPN of 2Hop to the OOPFE routing and we don't consider the "One broadcast" process.

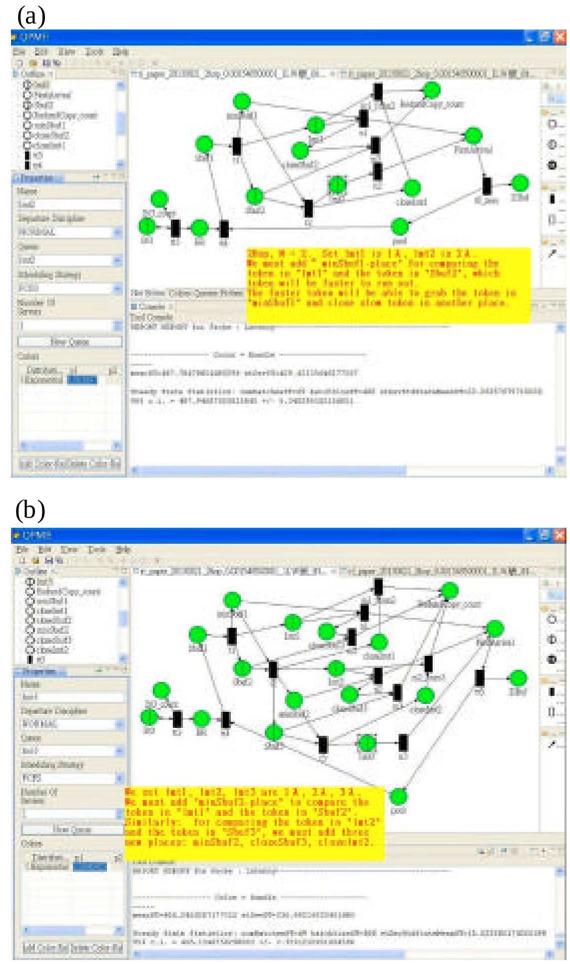

Fig. 5(a-b): Another equivalent Petri Net expression for 2Hop, (a) N = 2 +1. And Imt1, Imt2 set 1λ, 2λ, 3λ and (b) N =3 +1. And Imt1, Imt2, Imt3 set 1λ, 2λ, 3λ

Method to transfer the Markov chain into QPN for Latency: To model the Latency of OOPFE, we will transfer then basically Markov state transition diagram into QPN. In order to facilitate discussion and quickly to create model, we first omit the "One Broadcast" process and stay this discuss in later chapters. Now, only focus on the "One-Copy" process in OOPFE.

From Fig. 4, the Markov state transition diagram can be converted to the simulation of 2hop. There are other methods to express. Now we present another interesting approach and show in Fig. 5a and b. These Figures are also to model 2hop routing and completely equivalent results. Please compare the difference with earlier discuss in Fig. 2 and 3.

In this case N = 2 +1, we set the parameter, in Imt1 set 1λ, in Imt2 set 2λ. And we should add a new place, named as "minSbuf1 place", to check while one is the first out between "Imt1 place" and "Subf2 place". And, the first out token must close another exit. For example: "closeSubf2 place" will close the slower "Sbuf2 place" and the "closeImt1 place" will close the slower "Imt1 place".

In the preceding Figure, about the token choice, why we choose only the arrival time of the token with the faster one? The reason is that, in the original state diagram, we can select the minimum value of Petri Net diagram the express the probability.

For example: if there are two Queueing places in QPN, the first λ = 1/10, another λ = 1/5. In other words, the first place, expect 10 seconds per token, the second place, desired 5 seconds per token. So, after 15 seconds, the average numbers of randomly generated token are 5. Also, the exports of these two places, the probability which has some token are "10:5". So, how express the probability in the QPN? In order to find the first time to encounter the destination node, so if there are two or more states, we only care about the first arrival time.

So, we add the minimum concept in QPN design. In the preceding example to illustrate that, we set a minimum mechanism at the entrance of two Queuing place, the λ = 1/10 and λ = 1/5. We look at the export of these two Queueing place, then, the first appear the token is the smallest Latency. And the place λ = 1/5, there will be the minimum value on the probability of about 10/(10 +5).

Refer to Fig. 5a is another method to represents the Petri Net of 2hop routing. If N = 2 +1. And, we set the parameter of "Imt1" is 1λ and "Imt2" is 2λ. We must add "minSbuf1-place". Compare the token in "Imt1"and the token in "Sbuf2", which token will be faster to run out. The faster token will be able to grab the token in "minSbuf1" and close slow token in another place. For example: the token in "closeSbuf2" can close the slower token in "Sbuf2". On the contrary, the token in "closeImt1" can close the slower token in "Imt1".

Similarly, in Fig. 5b, shows another Petri Net to represent the 2hop and still completely equivalent expression. The N = 3 +1. And Imt1, Imt2, Imt3 set 1λ, 2λ, 3λ. We must add "minSbuf2-place" to compare the token in "Imt1" and the token in "Sbuf2". Similarly: for comparing the token in "Imt2" and the token in "Sbuf3", we must add three new places: minSbuf2, closeSbuf3, closeImt2.

From Fig. 5a, b, Fig. 2 and 3, the Latency is 409.76 +/- 3.49 in Fig. 2 and the Latency is 406.13 +/- 3.73 in Fig. 5b. We can find the value is more then 95% confidence interval and we get two equivalent methods to model the routing.

CONCLUSION

In this study, we have explained the OOPFE-routing method. If we omitted the OB-process, we will find the equal effect with the 2hop-routing. Then, we further build two equivalent ways to model 2hop-routing. And, the value of simulate results compare with the value of theory are more than 95% confidence interval.

Through we use QPN to model, we can quickly get the desired results and we can pay attention to important parameters for detailed analysis. And we can further do the effectiveness mathematical analysis.

We also found there is a big problem for using QPN-tools, that is, if the number of states are too much (for example, the value of N is larger), there will be state explosion problem, so we will continue to improve the simulation methods and improve the simulation tools for more flexibility.

The future, we will continually use the QPN tool to make more realistic simulation. Not only the routing problems but also web performance analysis or other mechatronics system analysis.

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